Space Weather Technical Forecast

Issued on Sunday, 26 November 2023 at 01:17 Local

This technical forecast provides a four day assessment of space weather events. The probabilities stated below are for reaching or exceeding the given levels. For more information about space weather impacts please see the Met Office Space Weather Scales https://www.metoffice.gov.uk/weather/learn-about/space-weather/uk-scales

Space Weather Forecast Headline: Isolated M-class flares/R1-R2 Radio Blackouts likely throughout. Chance of G1 Geomagnetic Storms Days 1-2 (25-26 Nov).

Analysis of Space Weather Activity over past 24 hours

Solar Activity: Solar activity has been Low, with a peak C4.4 flare at 25/1440 UTC from AR3503 close to the Eastern limb. There are twelve sunspot regions currently on the visible disc. Near centre disc in the northern hemisphere there is a cluster of four sunspot regions that appear to be contained within the same area of plage and connected magnetically. AR3492 (Chi/Beta) is the largest group within the region and consists of two large unipolar spots trailed by a number of weak spots, many of which are little more than pores. AR3490 (Dac/Beta) in the north of the group has simplified slightly over recent hours. AR3502 (Dao/Beta) and AR3491 (Hsx/Alpha) to the south of AR3492 remain remains largely unchanged.

The largest group currently on the disc is AR3500 (Dkc/Beta-Gamma-Delta) in the southeast. This compact region primarily consists of a large delta spot and other mature spots in close proximity. AR3499 (Dai/Beta) in the southwest has seen some slight growth.

The other groups on the disc are smaller and more magnetically simple than the previously mentioned regions.

Although CMEs have been observed on coronagraph imagery leaving the Sun over the past 24 hours, confidence is high that these do not have Earth-directed components.

Solar Wind / Geomagnetic Activity: Solar wind parameters, as measured by ACE and DSCOVR at L1 were initially at slightly elevated levels around 470 km/s, and saw a significant jump and minor discontinuity around 25/0800 UTC to Elevated levels with speeds of 530-580 km/s. This enhancement is indicative of a CME arrival at L1 and has been attributed to the arrival of the filament eruption CME from 22 Nov but could also show a connection to CH75/+ earlier than expected. Levels increased to strong at times with speeds of 570-620km/s from around 25/2030UTC and 25/2240UTC, before returning to elevated levels. Solar wind density was generally at above average levels, with a peak of 27 ppcc at 25/0847 UTC. The IMF was predominantly at moderate levels with a brief peak of 18nT at 25/0830UTC, before falling to weak levels from 252200UTC. The important north-south component (Bz) varied weakly at first, then from the CME arrival, the Bz has varied periodically and between +9/-16nT and since 25/0600 UTC has predominantly remained strongly negative (southward oriented), before varying weakly again from around 25/1900UTC. Phi angle was mostly positive (away from the Sun). The resultant geomagnetic activity was initially Unsettled (Kp3) and has been mostly at Active levels since the 25/0600-0900 UTC interval, however during the 25/1800-2100UTC interval it increased to Moderate storm (G2/Kp6) levels, before returning to active for the 25/2100-26/0000UTC level.

Energetic Particles / Solar Radiation: GOES16 high energy (greater than 10MeV) proton flux remained at Background levels. GOES16 high energy (greater than 2MeV) electron flux has been at Background levels throughout the period. The associated 24-hour fluence has remained below the Active threshold (1e8 integrated pfu) on a gradually declining trend. The fluence

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observation at 26/0000 UTC was 1.95e6 integrated pfu.

Four-Day Space Weather Forecast Summary

Solar Activity: Solar activity is expected to be Moderate with further isolated M-class flares (R1-R2, Minor-Moderate) likely and a slight chance of an isolated X-class (R3-Strong) flare. The main flare risk is from regions currently positioned on the eastern solar hemisphere and those in the cluster close to the centre of the disc in the north.

Solar Wind / Geomagnetic Activity: Two further CMEs feature in the forecast period. A filament eruption CME observed from late 22 Nov is forecast to arrive early Day 1 (26 Nov). A further CME resulting from the M1.1 flare from AR3499 on 24 Nov has been analysed and modelled as a likely miss, with just a slight chance of a glancing blow on Day 2 (27 Nov).

Solar winds are currently enhanced following the recent CME arrival and are at Elevated levels, around 550 km/s. There is some uncertainty if these elevated wind speeds are currently due to connection with a HSS from CH75/+ or due to lingering enhancement from the earlier CME. if we are enduring the lingering effects of the earlier CME we may see a decrease in the solar wind speed back to slightly elevated levels during the early period of Day 1 (26 Nov), before speeds increase again to elevated or perhaps strong levels during day 1 due to enhancement from the second CME arrival and HSS onset which could potentially coincide. As such there is significant uncertainty in the short term but speeds expected to be around 550-600km/s.

Geomagnetic activity is currently active (Kp 4), and may reduce to mainly Unsettled levels ahead of the next CME arrival early Day 1 (26 Nov), however this depends if we are already connected to CH75/+ in which case we may not see any reduction in geomagnetic activity in the short term. However on arrival of the next CME geomagnetic conditions of unsettled to G1/minor storm (Kp 3-5) conditions are probable, with a slight risk of G2/Moderate storm (Kp6) due to combined CME and HSS effects. Combined CME and HSS influences may extend a period of somewhat enhanced Geomagnetic into Day 2 (27 Nov), with Quiet to Unsettled levels (Kp 1-3) but should subside to become mostly Quiet (Kp 0-2) by Day 3 (28 Nov).

Energetic Particles / Solar Radiation: GOES16 high energy proton flux is expected to remain at Background levels. However, there is a slightly higher risk of observing S1/Minor Storm conditions compared to normal, given the number of sunspots currently on the disc and their propensity to move into a more favourable location on the disc for connection with Earth in the coming days.
Electron flux levels have recently fallen to Background levels following the arrival of the CME from early 22 Nov. Similarly suppressed flux levels are expected over the coming days given forecast combined CME and high-speed stream influence on Geomagnetic activity. High levels of election flux are unlikely to be reached until Day 3 (28 Nov) when there is an increasing chance that the reduction in the solar wind pressure following the CMEs and high-speed streams could allow electron flux to subsequently increase.

Fluence levels are expected to remain below the 1e8 Active threshold throughout the period with any notable rise not expected to take place until day 3 (28 Nov) or later.

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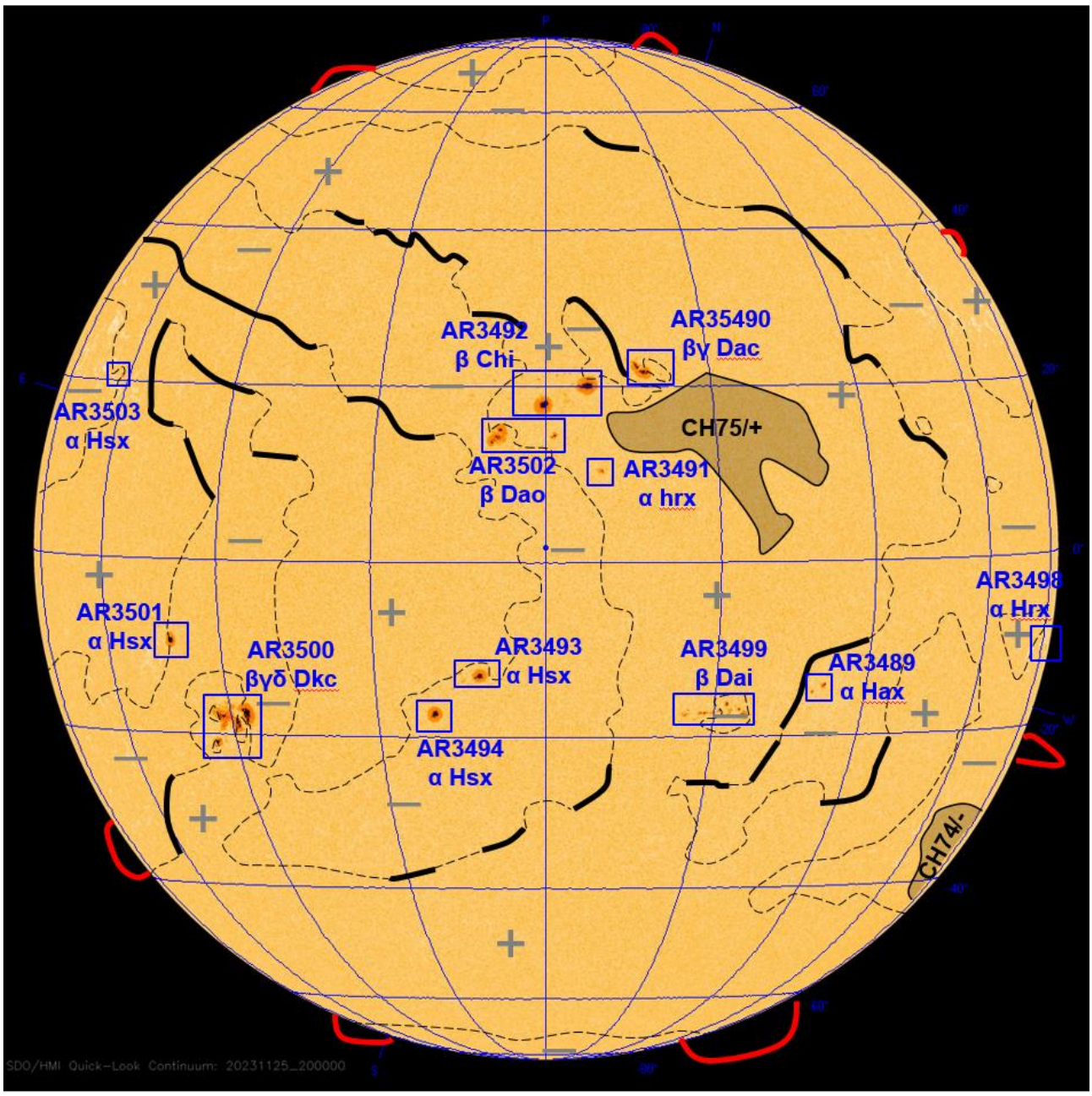
Figure 1. Solar Analysis Valid 25/2000UTC.



Key: Filament ___ , Prominence ___ , Magnetic Field Line - - - , Polarity +/-, Coronal Holes: Grey shaded area CHxx +/-, Sunspot groups 25xx - Mt Wilson α-β-βγ-βγδ and Zurich-McIntosh Axx etc.

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Geomagnetic Storms:
Although CMEs have been observed on coronagraph imagery leaving the Sun over the past 24 hours, confidence is high that these do not have Earth-directed components.

Three Earth-directed CMEs feature in the forecast. The first is from a filament eruption in the southeastern quadrant early on 22 Nov which is considered to have arrived earlier on 25 Nov, matching with Enlil modelling and the projected arrival time of this feature. A second, partial halo, CME was evident on LASCO and STEREO imagery from 22/2100 UTC directed mainly southwards. A coronal dimming spanning several hours preceded this appearance on LASCO imagery, starting around 22/1930 UTC in the vicinity of AR3489 and accompanied by two flare ribbons, indicative of post-eruptive magnetic re-connections in the Sun's corona following a filament eruption. Confidence is moderate that these observations are related, and for a CME arrival at Earth from this filament eruption around 26/0000 UTC, however only moderate confidence in the arrival of this feature so it may arrive during the UTC morning of Day 1 (26 Nov), although only moderate confidence in timing. The final CME in the forecast is associated with the 24/0933 UTC M1.1 flare from AR3499 in the southwest disc; this has been analysed and modelled as a likely miss below Earth's orbit with just a slight chance of a glancing blow on Day 2 (27 Nov).

Solar winds are currently at Elevated levels around 550 km/s having increased from around 470 km/s at the start of the period following the recent CME arrival. There is some uncertainty if these elevated wind speeds are currently due to connection with a HSS from CH75/+ or due to lingering enhancement from the earlier CME. If the current elevated levels are due to connection with the coronal hole, then this connection has occurred earlier than anticipated. On the previous rotation, this coronal hole was a much larger and darker feature that it appears currently on coronagraph imagery and resulted in speed of 570km/s and a period of several days at elevated levels, which is now possible will occur again. However if we are enduring the lingering effects of the earlier CME we may see a decrease in the solar wind speed back to slightly elevated levels during the early period of Day 1 (26 Nov), before speeds increase again to elevated or perhaps strong levels during day 1 due to enhancement from the second CME arrival and HSS onset which could potentially coincide. As such there is significant uncertainty in the short term.

Geomagnetic activity is currently active (Kp 4), and may reduce to mainly Unsettled levels ahead of the next CME arrival early Day 1 (26 Nov), however this depends if we are already connected to CH75/+ in which case we may not see any reduction in geomagnetic activity in the short term. However on arrival of the next CME geomagnetic conditions of unsettled to G1/minor storm (Kp 3-5) conditions are probable, with a slight risk of G2/Moderate storm (kp6) due to combined CME and HSS effects. Geomagnetic activity on the previous rotation was Kp 3-5 (Unsettled to G1/Minor Storm) associated with the HSS from CH66/+. Similar, or slightly muted, enhancement is expected to take place upon connection to the CH75/+ HSS, which again, we may already be under the influence of. Combined CME and HSS influences may extend a period of somewhat enhanced Geomagnetic into Day 2 (27 Nov), with Quiet to Unsettled levels (Kp 1-3) but should subside to become mostly Quiet (Kp 0-2) by Day 3 (28 Nov).

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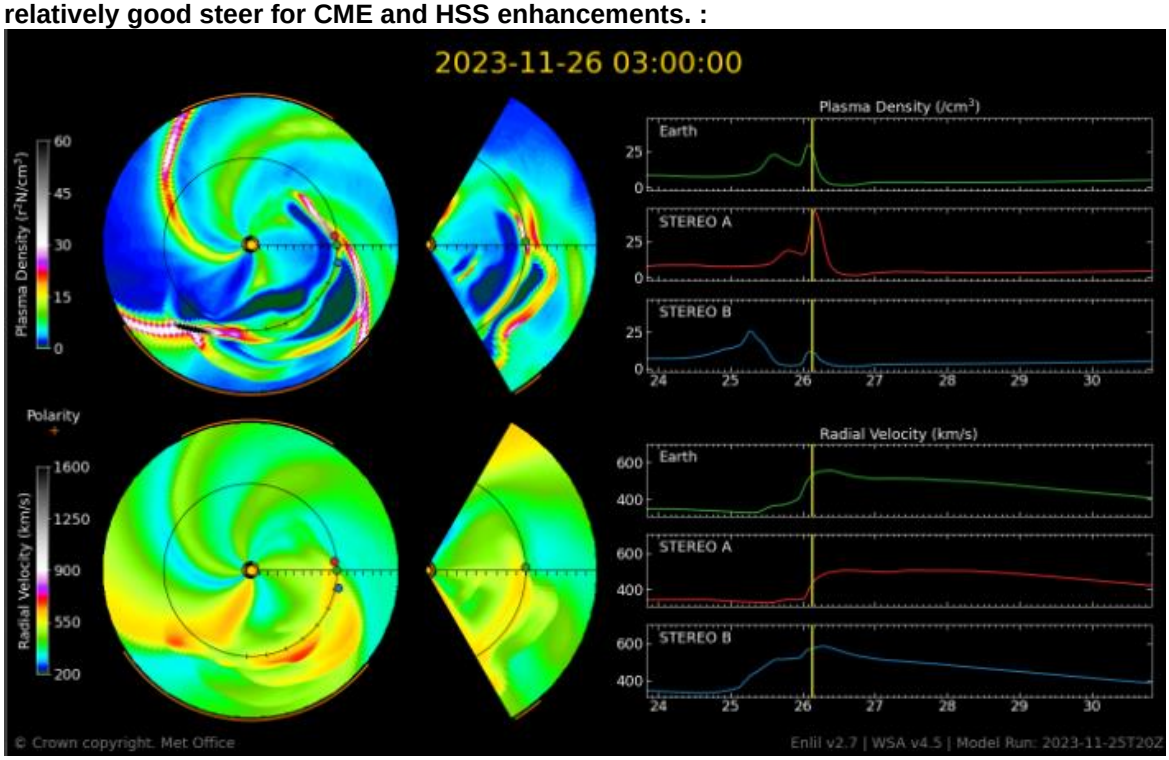
Geo-Magnetic Storm Probability (Exceedance)	Level	Past 24 Hours (Yes/No)	Day 1 (00-24 UTC) (%)	Day 2 (00-24 UTC) (%)	Day 3 (00-24 UTC) (%)	Day 4 (00-24 UTC) (%)
Minor or Moderate	G1 to G2	Yes	70	20	5	1
Strong	G3	No	20	1	1	1
Severe	G4	No	1	1	1	1
Extreme	G5	No	1	1	1	1

Geomagnetic Activity - Earthbound Coronal Mass Ejections

Date/time 21.5R (UTC)	Halo: Full or Partial	Source	Source Location	Estimated Speed	Estimated Arrival Time	Comments
23/0535	Partial	Filament Eruption	SE (near AR3489)	540 km/s	25/0000 UTC	Moderate/high confidence in arrival time.
24/1707	Partial	Filament Eruption	S central disc	522 km/s	27/1500 UTC	Slight change of glancing blow.

Figure 2 MOSWOC Enlil shower CME arrival Day 1(26 Nov) and connection to CH75/+. Shows a relatively good steer for CME and HSS enhancements. :



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Radio Blackouts - X-Ray Flares:

There are twelve sunspot regions currently on the visible disc. Near centre disc in the northern hemisphere there is a cluster of four sunspot regions that appear to be contained within the same area of plage and connected magnetically. AR3492 (Chi/Beta) is the largest group within the region and consists of two large unipolar spots trailed by a number of weak spots, many of which are little more than pores. AR3490 (Dac/Beta) in the north of the group has simplified slightly over recent hours. AR3502 (Dao/Beta) and AR3491 (Hsx/Alpha) to the south of AR3492 remain remains largely unchanged.

The largest group currently on the disc is AR3500 (Dkc/Beta-Gamma-Delta) in the southeast. This compact region primarily consists of a large delta spot and other mature spots in close proximity. AR3499 (Dai/Beta) in the southwest has seen some slight growth.

The other groups on the disc are smaller and more magnetically simple than the previously mentioned regions.

AR3498 will rotate over the western horizon on Day 1 (26 Nov). However, bright areas on SDO imagery and occasional CME activity just beyond the eastern limb suggests the presence of further active regions that are expected to rotate onto the visible disc by Day 4 (29 Nov). As a result, flare probabilities have been maintained at relatively saturated levels. Activity is expected to increase to Moderate, with further isolated M-class flares, and a slight chance of an isolated X-class flare.

X Ray Flares	Level	Past 24 Hours (Yes/No)	Day 1 (00-24 UTC)	Day 2 (00-24 UTC)	Day 3 (00-24 UTC)	Day 4 (00-24 UTC)
Probability			(%)	(%)	(%)	(%)
Active	R1-R2 M Class	No	60	60	60	60
Very Active	R3 to R5 X Class	No	10	10	10	10

Figure 3 GOES16 and GOES18 24 hours trace showing peak of C4.4:

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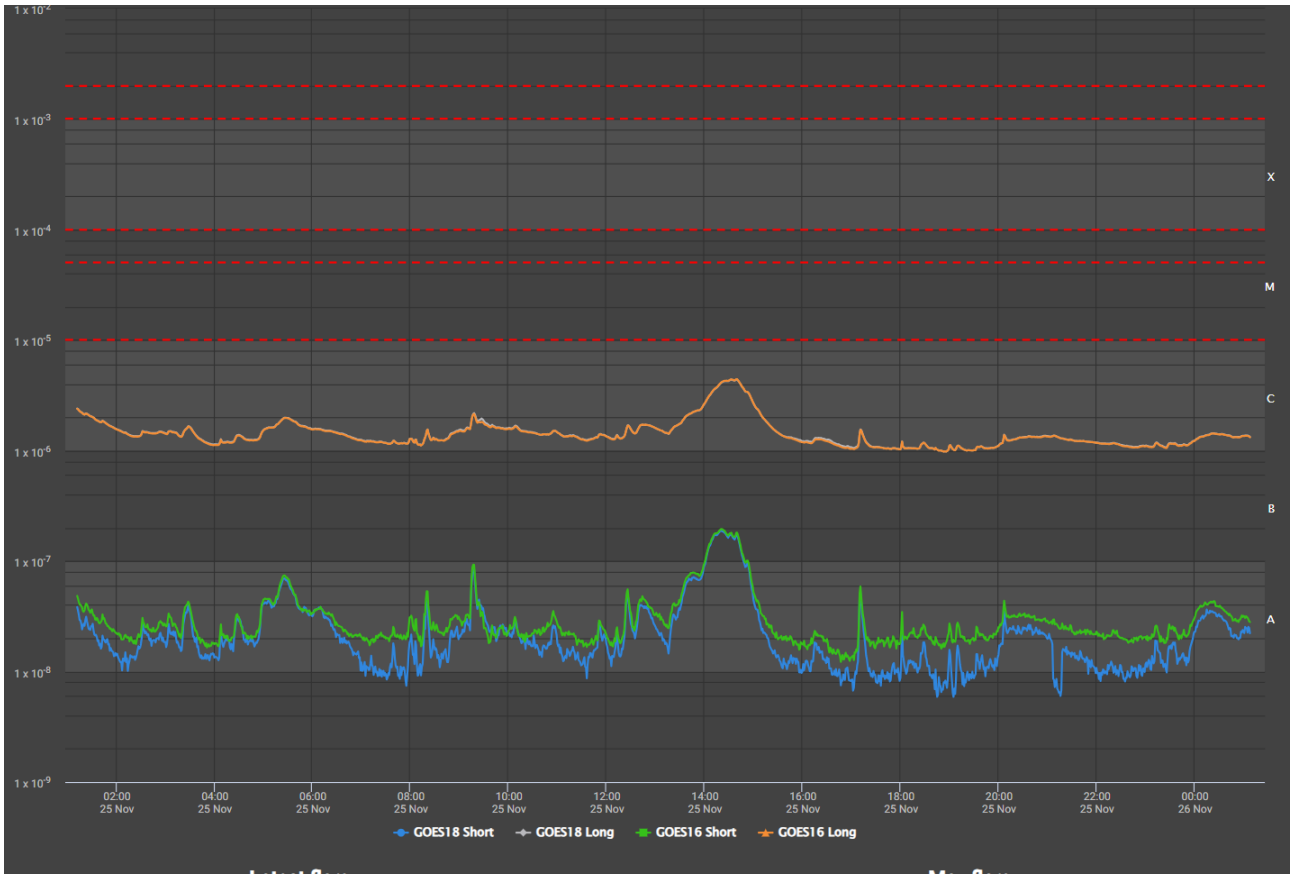

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Solar Radiation Storms - (High Energy Protons):

The high energy (greater than 10MeV) proton flux observed by GOES16 is currently at Background levels.

There are several moderately-large and fairly complex regions close to the centre of the disc in the northern hemisphere. These result in a slightly above background risk of an S1/Minor Solar Radiation Storm in the coming days. This risk remains small, but with a minor uptick in probabilities from Day 2 (27 Nov) when these groups move into a more favourable location for connection with Earth, as they move further into the western solar hemisphere, apparent from Earth.

Radiation Storms Probability (Exceedance)	Level (cm^{-2} sr^{-1} s^{-1})	Past 24 Hours (Yes/No)	Day 1 (00-24 UTC) (%)	Day 2 (00-24 UTC) (%)	Day 3 (00-24 UTC) (%)	Day 4 (00-24 UTC) (%)
Active	**≥ S1**	No	10	15	15	15
Very Active	**≥ S3 ***	No	1	1	1	1
* S3 ≥ 10 MeV ≥ 1000 pfu and / or ≥ 50 MeV ≥ 10 pfu. (pfu = $cm^{-2}sr^{-1}s^{-1}$)						

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High Energy Electrons Event (≥ 2MeV):

Electron flux levels fell to Background levels following the arrival of the CME from early 22 Nov. This suppression in electron flux is expected to persist for much of the forecast period, given combined forecast CME and HSS (CH75/+) influences on the electron belt and geomagnetic activity in the coming days. High levels of election flux may be reached Day 3 (28 Nov) or Day 4 (29 Nov) when there is an increasing chance that the reduction in the solar wind pressure following recent CMEs and high-speed streams could allow the Van Allen belts to relax and electron flux at GEO to subsequently increase. However for this to occur on Day 3 this relies on possible glancing blow CME on Day 2 missing Earth.

Fluence levels are expected to remain below the 1e8 Active threshold throughout the period. The Met Office REFM model forecast will not account for the recently observed nor the forecast CME arrivals, therefore will likely indicate higher fluence values than should be observed. A rising trend in the Recurrence forecast between Days 1 and 2 (26-27 Nov) is based on an earlier arrival time of the high-speed stream from CH75/+ and subsequent recovery of the electron belts on the previous solar rotation. Any notable rise is not expected to take place until Day 3 (28 Nov) or later

GEO Electron Environment	Level ($cm^{-2}\ sr^{-1}\ day^{-1}$)	Past 24 Hours (Yes/No)	Day 1 (00-24 UTC)	Day 2 (00-24 UTC)	Day 3 (00-24 UTC)	Day 4 (00-24 UTC)
Probability (Exceedance)			(%)	(%)	(%)	(%)
Active	≥ 2 MeV ≥ $1x10^{8}$	No	1	5	15	20
Very Active	≥ 2 MeV ≥ $1x10^{9}$	No	1	1	1	1

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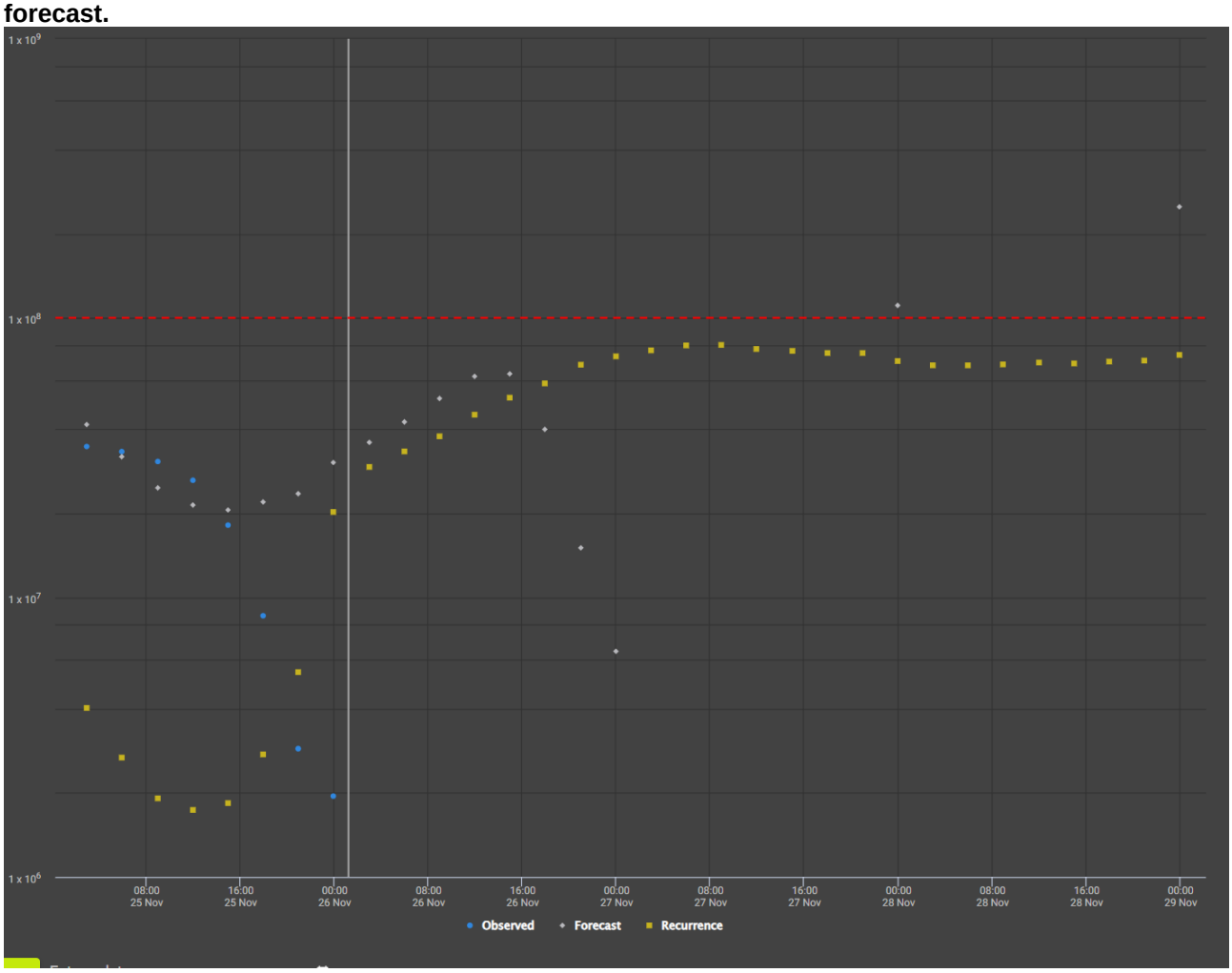
Figure 5: MOSWOC REFM considered to be giving a poor steer given complicated geomagnetic forecast.



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